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ABSTRACT

This paper develops a model for the Construction Industry and defines the various phases within the construction process. It is suggested that engineering education make students aware of the construction process and its divisions, and provide management training. (MLH)

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WHAT THE CONSTRUCTION INDUSTRY EXPECTS FROM ENGINEERING EDUCATION

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INTRODUCTION

The authors appreciate this opportunity to discuss the role of Engineering Education in the Construction Industry with you. Our points of view are those of a manager in Construction and a professor in Engineering-Construction education.

Our purpose is to:

Develop a model of the Construction Industry.
Define and examine the various phases within the construction process.
Review related historical backgrounds.
Assess the needs that exist in construction education.
Present our conclusions as to what the Construction Industry should expect from Engineering Education.

The Construction Industry is the largest and most dynamic conglomerate industry in the world. The impacts of the products of this industry range from nuclear power stations and 110 story skyscrapers through multi-state urban studies to single family residences.[1] The multitude of integrated operations within this dynamic Industry requires a multiplicity of professions and participants; Developer, Architect, Engineer, Planner, Lawyer, Financier, Builder Craftsman, Quality Assurer. Many of these fields are in their own right, an "Industry" within the recognized "Construction Industry". The relationship between these participants and the various phases can be seen in the model in Figure 1.

1. Shaffer, L.R. Research in Construction Management: Its Impact on Industry, Ninth Annual Henry M. Shaw Lecture Series, Department of Civil Engineering, North Carolina State University, Raleigh, North Carolina.

DEFINITIONS

To explain the Construction Process which is the Construction Industry, it is well that we state our definitions of the terms being used.

Construction Process: The integration of a series of essential operations to provide a functioning physical facility which will serve societal needs.

Life Cycle and Study Phase: To determine the estimated period during which a facility is expected to be serviceable and profitable. A detailed investigation and analysis conducted to determine the financial, economic, technical or other advisability of a proposed facility.

Planning and Design Phase: The art and science by which the properties of matter and the sources of power in nature are blended into a scheme to create a pleasing and economical facility.

Building and Erection Phase: The forming of a needed physical facility by combining men, machines, material, money and management.

Start Up and Operation Phase: To establish operational procedures from start up time, to enable personnel to be properly trained in the procedures and limitations of the facility.

Maintenance & Life Cycle Review Phase: The continual evaluation and review of the up-keep and changing technological needs of a facility and its users.

Project Management: The art and science of causing various operations in the construction process to integrate in a manner to meet the budget/time/quality requirements of the owner.

Engineering: The art and science concerned with the practical application of scientific knowledge in the planning, design and operational phases.

Architect: One who devises, plans, or creates in the planning and design phase.

Estimating: The art and science of placing a money/time value on a construction operation or process before the work is started and many times before the designs are completed.

The authors are aware that the model in Figure 1 and the associated definitions impart an extremely broad scope for the Construction Industry. It is essential, in determining educational programs, to understand the extent of the Industry and to not relate the Construction Industry to only the building and erection phase of the Construction process.

THE CONSTRUCTION PROCESS

(Participants and Phases)

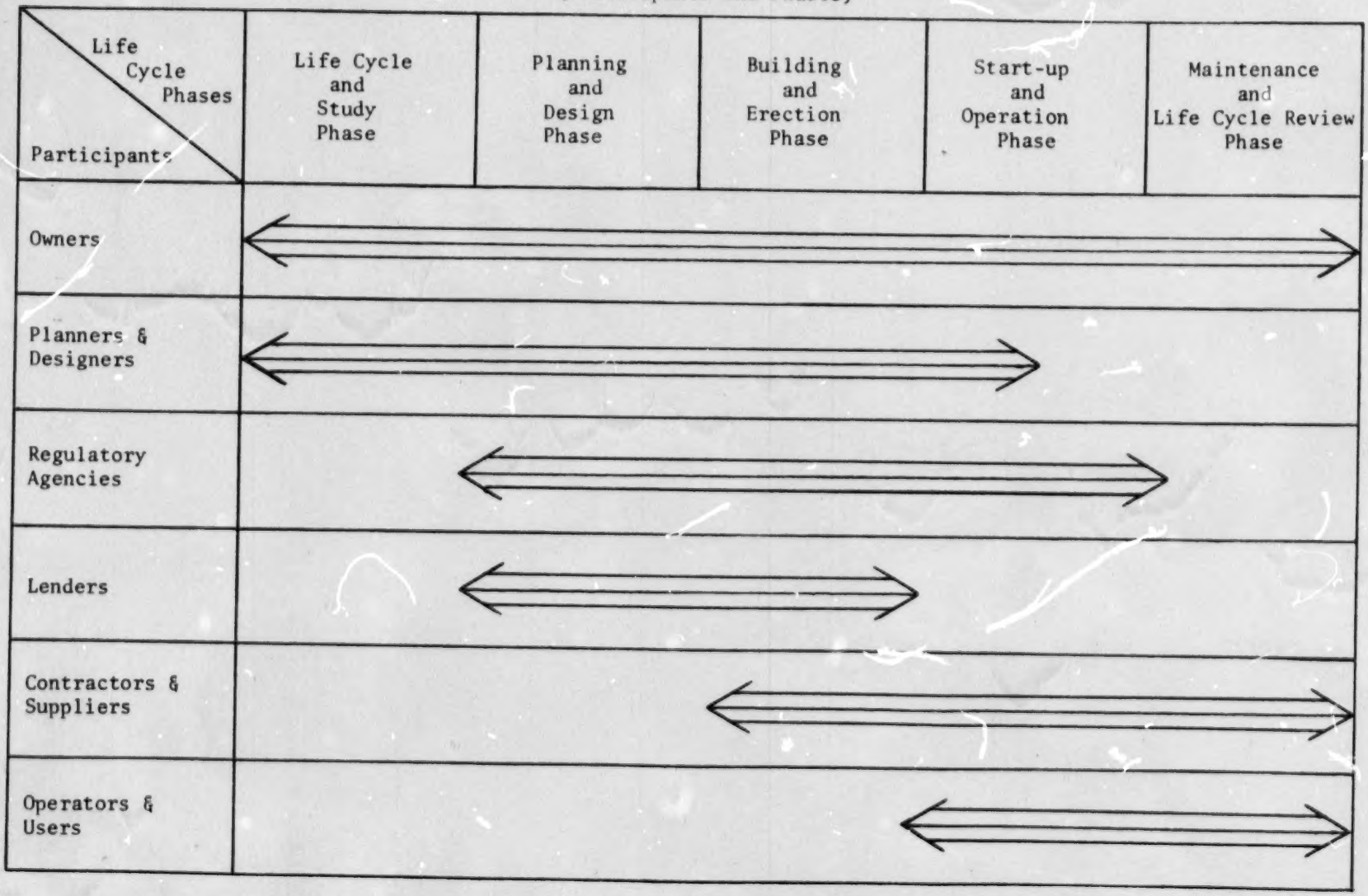

Figure 1

HISTORICAL

Construction management takes many forms, but Shaffer points out the CM form has been in existence since about 1750.[1] This confirms the point that many of the basic inter-relationships of the construction industry have existed for centuries, and many, before the time of Christ.

One source of information about this occurs in a wonderful book by Martin S. Briggs.[2] Much of the information that follows was drawn from this delightful work. The Egyptian craftsman was renown, but unfortunately the details of the management form in construction of that day is lost; overshadowed by scenes of thousands of slaves, straining under the whip to construct mammoth pyramids. There seems to have been a guild organization; skilled workmen were not allowed to change jobs for fear of them losing their skill. They were bonded to a King or Noble who performed all the building of any magnitude. The architect who designed the pyramids was a member of the King's Court. It is significant that his title was once known as the "royal axe-man".

During the golden age of Greece, manual labor was beneath the dignity of the citizens. It was fortunate there were a large number of slaves to do the work. Engineers and architects and gifted craftsmen existed even among the slaves. The identity of the architect was preserved, by recognition in the buildings, such as the Parthenon. The extraction of the word Architect is interesting; (Archi = Chief, plus tekton = worker).

The buildings of Imperial Rome were also erected by forced labor. Two classes of workers served on the project. The menial work, mostly hidden from view, was done by unskilled workers organized into "gangs". The artistic work was done by a higher class, who might be slave or free and who formed themselves into free societies (Collegia) which resembled the later guilds. Later, members of the Collegia became powerful and many strict rules of the Roman Empire were enacted which restricted the workman to follow a trade for life.

The Roman architect Vitruvius gave us his famous definition of the qualifications of an architect, which describes useful qualifications for the Construction Manager of today. "Let him be educated, skillful with pencil,

2. "A Short History of Building Crafts", Oxford Press.

instructed in geometry, know much about history, have followed the philosophers with attention, understand music, have some knowledge of medicine, know the opinions of jurists and be acquainted with astronomy and the theory of the heavens".[2]

During the eleventh and twelfth centuries, the rapid development of building in Western Europe was largely due to activity of the various monastic orders. The residents of the monasteries had to be their own builder and architect. Their immense buildings required a wide knowledge of construction and craftsmanship. The identity of the construction manager in monastery building has been obscured but various names were given. (Cementarius - stone mason; Ingeniator - master builder; Lathomus - stone cutter).

Gothic architecture replaced the Roman style by the end of the thirteenth century and with the change came a new organization for building. The master mason became important in the construction process. The guilds grew throughout Europe during the Middle Ages. A Mason's Guild was parallel to the Master of Arts in the university, that is the Guild of Letters. By serving an apprenticeship of seven years, he became a bachelor or companion and after acceptance of a proper work-thesis he became a master. The master-mason was the triple operation manager of architect, builder and clerk of the works.

An event happened in 1666 which had a profound effect on the Construction Industry. Dr. L.R. Shaffer notes "The General Contractor form of the industry in vogue today came as a result of the Great Fire of London in 1666. In order to respond to the rebuilding required, the general contractor form was created". Although the European forms of the Construction Industry, i.e., crafts, guilds, master-mason, were brought to this country, the industry here has a distinct form. Distances were so great that the mobility of craftsmen was a limiting factor. Early engineering education was largely through the military, e.g., West Point, 1802.

The point to be observed in this historical review is that the Construction Industry is sensitive, perhaps more than any industry, to social-political changes. The Industry has changed through a series of forms, depending on there social-political pressures.

The interrelation of the various operations or phases within the Industry have always existed. The Industry of the past was characterized by an abundance of materials, an unlimited resource of labor, and plenty of time. Technology was not lacking; we are amazed to this day with their amazing feats.

Today, the Industry faces limited resources both of labor and materials, and the cost associated with time is a major factor. Our technology and ability to manage is enhanced by using the computer.

Shaffer gives this description. "It has been popular in the last decade to brand the Construction industry as a "backward industry" i.e., an industry which resists change; an industry which is reluctant to adopt new methods, techniques and materials; an industry which does not foster research. The record shows that such accusations are truly unfounded. The industry responds positively and responsively to change which it can assimilate within the anatomy of its legal, social, financial and technical systems. In truth, the industry is even changing it's anatomy! Hardly the performance of a backward industry. Rather, the construction industry is responding to a mind-boggling awesome challenge thrust upon it by societal needs. Because of the population growth, it has been forecast that the construction industry in America will have to provide within the 30 year time period of 1970-2000, the equivalent of what has been built since 1492! Moreover, population is demanding that the quality of life made possible by facilities must be of a higher standard than previously, but yet at costs and in construction times which are reasonable. And this construction must be performed during an era when resources for construction is shrinking; both skilled labor and the common materials such as natural aggregates, asphalts, wood and cement. Complicating the challenge, is the environmental quality which construction must maintain during the process of building". 1

Change is occuring - more change will be necessary to meet the challenge of today. In many cases, the changes are being dictated by the client/owner. Construction management, C.M., was given a big boost by the General Services Administration when they began calling for bids from CM for selected projects. Many industrial clients have learned that there are viable alternates to the

Owner/Designer-Builder Mode of construction, which achieve better cost/time results.

In many cases, the changes are wrought because of competitive pressure from within the Industry. The construction process becomes more effective, hence more competitive when formal procedures of management are used. Larger cost savings are possible when Designer-Builder work throughout the construction process by an exchange of cost awareness.

The construction process has been lengthened because of a multitude of time consuming permits of all kinds, many requiring public hearings. The commitment of financial support must be sensitive to this new dimension. Life-cycle designs and economies are further evidence of the diminishing building resources. Within the construction industry, a multi-level of businesses and professions are trying to assess how they should respond to the challenge. Collectively, they look to the Educational System of our country to provide ideas and leadership.

What Can The Construction Industry Expect From Engineering Education

First, and foremost, acknowledge that the Construction Industry is changing. A continued discussion of tradition and rights and practice will not provide solutions.

Second, we must recognize the Construction Industry as a process - an integrated process requiring constructors who understand the process and how it functions. The construction participants must be educated in a working knowledge of the process, regardless of what operation or phase they desire to be a part of. It is our firm belief that the process should be taught first and the specific skills required in the various operations should be acquired afterward.

Traditionally, in Engineering Education, the skills are taught first with the application of these skills introduced and presented second. This is generally true in all science oriented curriculums, where the scholar may enter an as yet undefined area of study and research. The construction process within the Construction Industry is well defined and those persons being trained for management positions within this process should understand the process first.

Third, we must use the technical capacity of Engineering Education to develop management techniques for the industry. Engineering Education has provided the majority of construction managers in the past. However, this is changing - - and the change will accelerate toward institutions that offer Construction Management in Schools of Construction. An interesting statement about engineers as managers is "The management of many engineering companies like my own has been drawn largely from those whose basic education has been in engineering. This has arisen not because engineers make the best managers, but because the largest volume of talent in engineering companies has been among professional engineers. Nevertheless, the practice of engineering does develop many attributes needed in a manager and particularly in top management. The habit, for instance of trying to ensure that all the facts which bear on a situation are known before decisions are taken and the insistence that these facts, wherever possible, should be in the form of

numbers rather than feelings and opinions. The experience of having to make decisions within the limits by what is physically possible tends to develop the necessary hard and realistic approach to decision making".[3]

Please note, the author refers to the attributes as developed in the "practice of engineering". This confirms the observation that Engineering Curriculum does not provide room for engineering management courses. We believe that it is essential that undergraduate engineering education require a series of courses spread throughout the program which will instruct the engineer about the Industry, not just the particular specialty or phase he may choose.

It is essential that each constructor participant in the industry have more than just an awareness of the other member participants. Those in the building and erection phase must understand the planning and design phase to the extent that coordination is possible and competent management is possible. The planning design phase must understand the building and erection phase for the very same reasons. We see the manager of the Construction Industry Project coming from all levels and operations and specialties. The qualifications for the position are evident. The competency to fill the position is more a product of a total understanding of the process and the ability to manage the process, than any particular level of technical skill. This factor is important in a determination of who should be authorized or licensed to hold the position of Construction Manager. He must qualify as a manager first; as a specialist secondly, if he so chooses.

Conclusions

The Construction Industry needs changes in educational patterns which will provide better educated people for the Industry. Construction must be accorded primary position of prominence within the University structure. Schools of Construction within the University are a needed and practical method of providing the highly educated people that are needed. This cannot be accomplished unless engineering education participates in helping to bring about the establishment of schools of Construction. Fragmentation has long been the mark of our

3. Pearson, Sir Denning. The Present State of Engineering - Bridge Between Science and Industry, Fawley Foundation Lecture, November 18, 1965.

Industry. In uniting, to provide Construction Education as a joint venture of all the participants, we will destroy fragmentation at the educational level and force it out as a factor at the market place. The gain will be to all - particularly to society, who is demanding the best we can provide.